Rocky Mountains Southwest Great Plains

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Evaluating Use of an Ultrasound Device to Measure Distances to Foliar and Woody Targets

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An ultrasound device was tested to evaluate its effectiveness in measuring the distances to vegetative objects under field conditions. The measuring device emits a high frequency sound wave that is aimed at a target. The elapsed time from signal emittance to return is converted to a distance estimate. Although this device can successfully measure distances to foliar targets under ideal conditions, field testing demonstrated that it is not well suited for use on forest plots. It appears that the target surface and inclination, wind, and ambient noise degrade sensor accuracy under field conditions.

Keywords: Ultrasound measurements, vegetation structure, shrub cover

Introduction

In the extensive forest inventories conducted by the USDA Forest Service, Forest Inventory and Analysis Projects, distance measuring is important in assessing the vegetation on 1-acre plots. Most attempts at measuring foliar characteristics with instruments have been directed at biomass (Tucker 1980) and have used non-distance measuring methods such as electrical capacitance (Fletcher and Robinson 1956), microwave attenuation (Crawford and Stutzman 1983), radiation attenuation (Mitchell 1972), and spectroradiometry (Pearson et al. 1976). Distance measurements have been used in predicting population densities, as among individual trees (Cottam and Curtis 1956), and also to quantify plot characteristics such as understory vegetation density and canopy height above ground level. This study evaluates the performance of an ultrasound distance measuring device for obtaining the necessary distance estimates.

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Study Area

Fourteen test sites were chosen in the foothills west of Fort Collins, Colo., to represent a wide variety of vegetation cover and types common to the forest and rangeland of the area. Three plots were in riparian areas, the remainder along the drier slopes of the foothills. The overstory vegetation consisted of cottonwoods (*Populus deltoides*) and aspen (*Populus tremuloides*) at the riparian sites, and ponderosa pine (*Pinus ponderosa*) on the steeper slopes of the foothills. The understory vegetation was comprised mainly of rabbitbrush (*Chrysothamnus* spp.) which was found at both riparian and sidehill sites, and bitterbrush (*Purshia* spp.) on sidehill sites.

Methods

The ultrasound device, which relates distance measure to the elapsed time between emittance and return of a sonic pulse, was first tested in the laboratory. The sonic signal has a frequency of 40 KHz and a pulse rate of approximately 1 per second. Materials with high sonic ab-

sorption will not reflect a signal, hence no distance measure can be made. The laboratory tests indicated that foliar targets acted as good reflectors of the ultrasound energy. Woody stems did not act as good sonic reflectors; however, it was decided to attempt field measurements to test whether trunk size and species type influenced the ability of the sensor to measure woody targets. Leaf phenology (e.g., dead or wilted leaves) and leaf size did not affect strength of the return signal in the laboratory, where a leaf with a diameter of 1 inch could be detected at a distance of 7 feet. The minimum distance measurable by the device is 2.6 feet.

At each site, a square plot 1/20th of an acre in size was established and divided into quarters. From the center of each quadrant, 16 radial measurements were taken (every 22.5 degrees) of distance to the nearest shrub crown or tree. This resulted in 64 distance measurements for each plot. If the center point of the quadrant was occupied by shrub cover or a tree, all distances were recorded as equal to zero. To test the accuracy of the ultrasound measurements of horizontal distance to shrub canopies, the distance to the outer surface of the canopy midsection was also measured with a tape. To measure the height of the overstory, the ultrasound device was positioned at four locations 1-foot away from the main stem and measurements taken vertically to the bottom layer of the tree canopy. These measurements estimated the average height of the canopy base above the ground.

Results and Discussion

For the ultrasound device to work properly, the return signal must be detectable by the sensor. The most important factors controlling the strength of a return signal was target surface and angle relative to the sensor. The ultrasound sensor works best with a target that is perpendicular to the signal path. A target that is not perpendicular may reflect the signal away from the sensor, resulting in no measured distance, or may cause an inaccurately long measurement because the signal reflects off several different surfaces before returning to the sensor. Although empirically developed prediction equations might be able to compensate for such bias, not enough data was obtained to test this hypothesis. In the field, there is little chance of all leaves being perpendicular to the signal path. However, many leaves at various orientations to the sensor often provided enough effective area to return a signal from the shrub canopy or lower tree canopy.

In the field, virtually no signals could be received from the main stem of trees regardless of trunk size or species type. Bark composition and texture is assumed to be the primary reason for this problem, as angle to the sensor and target area should have been sufficient for measurement by the device. Measurements to the base of the overstory canopy also could not be obtained. The small total leaf area for both pines and hardwoods may not have offered sufficient area to reflect the signal. Because of the higher number of return signals for the understory shrub, emphasis was placed on this aspect of the study.

The failure of some signals to return from the shrub vegetation was apparently caused by leaf orientation. In an attempt to solve this problem, the sensor was vertically panned in relation to the shrub target. This procedure was expected to increase the number of measurable horizontal return signals. The use of the panning procedure did increase the number of return signals; however, even with this method the ultrasound device produced distance measures for only 29% of the targets within the quadrant, (not including zero distances; i.e., when sensor location was within 2.6 feet of shrub canopy). Leaf angle and wind effects were believed to be the principle causes for lost signals.

Depending on shrub type being measured, leaf angle varied greatly. Leaves parallel to the signal path (e.g., facing skyward) do not provide sufficient area for signal reflection. Many small-leaf shrubs presented this problem in the study area. A shrub may have dense leaf structure, but the inclination of the leaves makes it impossible to detect with the ultrasound device. In effect, the signal traveled past the outer leaves and was scattered within the shrub canopy.

It was observed that as wind speed increased the number of measurable return signals decreased. Return signals obtained from a target under calm wind conditions disappeared if a sudden gust of wind developed. This effect appears to be caused by interaction of wind and the target. The perpendicular position of the foliar surface area relative to the sensor necessary to reflect the sonic signal is lost because of the continuously shifting position of the leaves. Other possible hypotheses include signal deflection and a doppler shift of the signal. No rigorous experiments were performed to test these alternative hypotheses. However, a simple laboratory test with a high-speed fan directed at the signal path did not degrade signal response.

A regression analysis between the ultrasound and tape measurements was made to test the accuracy of the distances acquired by the ultrasound device; the no-return cases were not included in this analysis (fig. 1). From the obtained return signals, an R^2 value of 0.651 was calculated. The low correlation is due to the inability of the ultrasound device to measure short distances (<2.6 feet), which are recorded as the minimum distance. Other sources of variation could be the panning procedure in which the device may measure to the top or base of the shrub canopy while the tape measurements were taken to the outer surface of the canopy midsection and the effect of signal scattering within the shrub canopy before the signal is reflected back to the sensor. While this indicates the inaccuracy of those measurements obtained by the device, it does not fully indicate the potential for field use of this device. A more representative analysis of the study would have to include the inability of the sensor to detect certain targets. This analysis would, therefore, include the no-return measurements in some fashion, the most logical being is to conclude the sensor did not detect anything in the path of the signal. A longest possible measurement was therefore assessed to each case of no return signal. Using this method, an R^2 value of 0.326 was calculated from a representative sample of the 386 possible measurements.

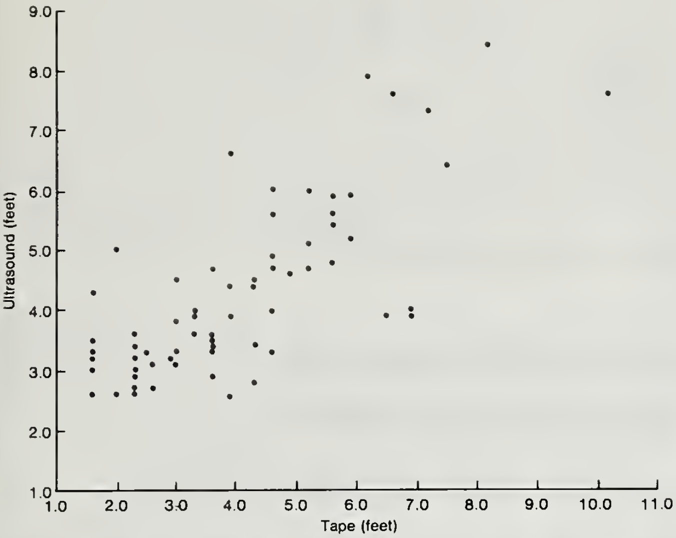

Figure 1.—Scattergram of ultrasound distance measures versus tape distances: $Y = 0.622x + 1.74$ $R = 0.807$

Conclusions

The ultrasound device did not perform well as a measuring tool under field conditions, and further use in such applications is not recommended. The limited success in the field may be attributable to wind and leaf angle. For obtaining the distance estimates, a tape measure would provide more consistent and reliable results.

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